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(54) GAS-TURBINE PLANT

(71) We, BBC BROWN BOVERI & COMPANY LIMITED, of Baden, Switzerland, a Swiss Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to gas-turbine plant with a heat exchanger connected upstream of the turbine to heat the working medium, and with a heating device for the medium after at least the first turbine stage.

If, in a plant of this kind, the heat exchanger has thoroughly cooled, as is the case when the plant has been shut down for any length of time, the working medium, which on expanding in the first turbine stage(s) through which it passes undergoes a further temperature drop, is cooled to such an extent, depending on the turbine inlet temperature, that temperatures below 0°C can occur. As a result, these turbine stages are themselves sharply cooled, and in addition, owing to this large temperature difference, correspondingly severe thermal stresses occur in the subsequent heating device. To keep these stresses within acceptable limits the loading rate on starting the gas turbine must be kept low. This gives rise to reduced throughput which, in the case of exhaust-gas heat exchangers, has the effect of prolonging the warm-up time and the starting process.

There exists the possibility of warming up the heat exchanger direct with an additional heating device for the purpose of starting, but even this would not significantly shorten the starting time, and the higher fuel costs and especially the additional cost of construction required would be further disadvantages.

A long starting time is particularly undesirable in the case of air-storage gas-turbine plants, as these are operated as peak-load installations and are intended to provide high output as fast as possible.

The present invention resides in a gas-turbine plant including a heat exchanger connected upstream of the turbine to heat the working medium, a heating device for heating the medium flowing through the turbine, connected after at least the first turbine stage, and a bypass which leads to the heating device from a point located between the heat exchanger and the first turbine stage and incorporates a first shutoff valve, a second shutoff valve being provided between the said point and the first turbine stage.

The invention provides plant which, while avoiding the disadvantages inherent in known installations, can be started quickly, and with this aim can be achieved with a minimum of construction costs.

The invention is particularly applicable to air-storage gas-turbine plants.

When operating the gas-turbine plant described, the procedure is that on starting the gas-turbine the flow medium is made to bypass the first turbine stage or stages by closing the valve in the section of pipe between the branch point on this connecting pipe and the first turbine stage or stages, and opening the valve in the branch pipe leading from the branch point to the heating device, the medium thus passing first to the subsequent turbine stages *via* the heating device. When the heat exchanger connected ahead of the first turbine stage or stages has been sufficiently heated, preferably to between 50 and 100% of its means operating temperature in °C, the valve mentioned second above is closed in accordance with a prescribed schedule, and the first-mentioned valve is opened.

By means of the method described, the flow medium undergoes no significant temperature drop even at the beginning of the starting process, and enters the heating device, in which the working medium is heated before passing into the following turbine stages, at a temperature which is not so low as to give rise to unacceptable thermal stresses. The rate of loading on startup can therefore be relatively high, and the plant can produce high outputs after a short starting time. During the starting phase, during which at least the first turbine stage is bypassed by the flow medium, only the power contributed by this stage is not available, but this is of little importance compared with the other

advantages. The fact that throughput can be high even during starting means that the exhaust-gas heat exchanger heats up quickly, which in turn also helps to keep the starting time for the plant comparatively short.

An example of the invention is shown schematically in the accompanying drawing, which shows a part of an air-storage gas-turbine plant. A gas turbine has a high-pressure section 2 and low-pressure section 6 mounted on a common shaft 7. During charging operation an electric generator 8 functions as a motor and drives a compressor (not shown) which charges a storage container (also not shown). In peak-load operation the generator 8 is driven by the gas turbine, which draws its working air requirement from the storage container.

Couplings 9 and 10 are so designed that they allow the various machines to be connected and disconnected for the operating modes stated.

The working medium (air, for example) coming from the storage container enters the heat exchanger 1 at 14, flowing in the direction of the arrow. The temperature of the medium to be heated is comparatively low, preferably below 100°C. In the normal operating mode, the working medium leaving the heat exchanger passes through pipe 11 into the high-pressure section 2 of the gas turbine, and from there *via* pipe 15 to a heating device 5, which in the present case is a combustion chamber into which fuel is introduced at 16.

Having been heated in the combustion chamber, the working medium passes *via* pipe 17 into the low-pressure section 6 of the gas turbine, and thence through pipe 18 to the exhaust-gas heat exchanger 1, where it heats the working medium coming from the storage container and entering the heat exchanger 1 at 14. The cooled medium then passes to a stack via pipe 19. At junction point 13 a bypass pipe 12 branches off pipe 11, this pipe 12 leading direct to the heating device 5 and incorporating a shutoff valve 4. The section of pipe 11 between junction point 13 and the high-pressure section 2 of the gas turbine contains a shut-off valve 3. In the normal operating mode, valve 3 is open and valve 4 closed.

On starting the plant, however, the high-pressure section 2 of the gas turbine is bypassed by closing valve 3 and opening valve 4, so that the flow medium is led direct to the low-pressure section 6 of the gas turbine by way of the heating device 5. As soon as heat exchanger 1 has reached a sufficiently high temperature, valve 4 is closed in accordance with a prescribed schedule, and at the same time valve 3 is opened. This procedure accomplishes the transition to the normal operating mode which, as described above, ensues with flow admission to the high and low-pressure sections of the gas turbine.

The invention is not limited to the example described. Various modifications are conceivable regarding construction and flow configuration. Thus, the invention is applicable to a gas-turbine plant which operates without connection to an air-storage container, in which case the working medium passes direct from the compressor (not shown) connected at 10, *via* pipe 14 to the heat exchanger 1.

The invention can also be applied to a gas-turbine plant of the closed-circuit type, in which the heating device comprises a separately heated heat exchanger (instead of the combustion chamber of the above example) located between the high-pressure section and the low-pressure section. In this case, working medium coming from the compressor is heated in the heat exchanger situated ahead of the first turbine stages by working medium leaving the low-pressure section of the turbine, and during the starting process the working medium bypasses the high-pressure section of the turbine and is fed direct to the separately heated heating device, from where it flows to the low-pressure section of the turbine, while the working medium coming from the low-pressure section of the turbine, having given up part of its remaining heat in the abovementioned heat exchanger (which functionally is eqivalent to the heat exchanger 1 in the drawing), undergoes further cooling and then returns to the compressor, thus completing the circuit.

The structural arrangement of the gas-turbine plant of the invention can also assume a variety of forms. The layout can be such that on starting, only the first turbine stage, or the first stage and a number of succeeding stages, is bypassed by the working medium. Depending on the particular circumstances, it would also be possible to connect two or more heat exchangers ahead of the first turbine stage, and if necessary also provide more than one heating device.

Finally, it would also be possible to modify the example shown in the drawing in such a way that the heat exchanger 1 is heated not by exhaust gas from the gas turbine stage and incorporates a first shutoff has passed through the heating device 5.

WHAT WE CLAIM IS:—

1. A gas-turbine plant including a heat exchanger connected upstream of the turbine to heat the working medium, a heating device for heating the medium flowing through the turbine, connected after at least the first turbine stage, and a bypass which leads to the heating device from a point located between the heat exchanger and the first turbine stage and incorporates a first shutoff valve, a second shutoff valve being provided

between the said point and the first turbine stage.

2. A gas-turbine plant as claimed in Claim 1, in which the heat exchanger is arranged to be heated by exhaust gas from the gas turbine.

3. A gas-turbine plant as claimed in Claim 1 or 2, in which the temperature of the medium entering the heat exchanger where it is heated, is below 100°C.

4. A gas-turbine plant as claimed in Claim 1, 2 or 3, forming a part of an air-storage gas-turbine plant.

5. A gas-turbine plant as claimed in Claim 1, 2, 3 or 4, in which the heating device is a combustion chamber.

6. A method of operating the gas-turbine plant as claimed in Claim 1, in which on starting the gas turbine the working medium is made to bypass the first turbine stage or stages by closing the second valve and opening the first valve, the medium thus bypassing the first stage or stages and passing to the subsequent turbine stages by way of the heating device, and in which when the heat exchanger has been sufficiently heated, the first valve is closed in accordance with a prescribed schedule and the second valve is opened.

7. A method as claimed in Claim 6, in which the first valve is closed and the second valve opened when the heat exchanger has been heated to between 50 and 100% of its mean operating temperature in °C.

8. A method of operating a gas-turbine plant, substantially as herein described with reference to the accompanying drawing.

9. A gas-turbine plant substantially as herein described with reference to the accompanying drawing.

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1474779 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale